Low-Energy Wireless Communication Network Project

Mobility Model for Task Two
—Maximum Area Coverage (1)

- We have done fixed trajectory mobility model, now we consider deploy mobility model (airborne).

- Suppose there are n nodes, each of which serves as a center of a circle with a given radius r. There is a possible area that can be covered by each of these circles.
- Under this scheme, there is an union area coverage for these circles, which are centered by these n nodes.
- **Mobility Goal:** The mobility goal is to achieve maximum union area coverage.

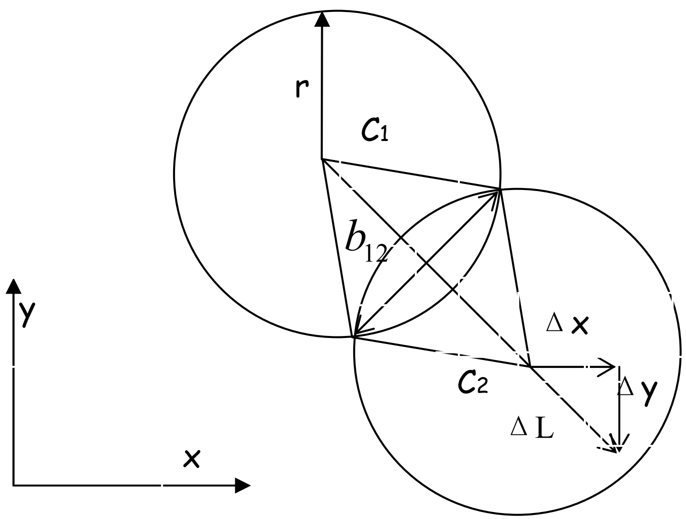
Mobility Model for Task Two
—Maximum Area Coverage (2)

- Constrains are as follows:
  - **Boundary Constrain:** There also exists a closed boundary. For each of these circles, if its covered area exceeds the boundary, then the exceeded area should not counted for the whole Union area.
  - **Overlap Constrain:** The overlap area of these circles can be counted only once.

Mobility Model for Task Two
—Maximum Area Coverage (3)

- The mobility model is described as follow:
  - **Initial position:** Each node Starts at some initial position within a given global boundary.
  - **Movement direction:** Each node moves to an undetermined position with some randomness. The direction of next step for a node to move is determined by the position of the other nodes and its current position.
  - **Movement termination:** The movement of the nodes terminates when the maximum area coverage is achieved, which characterized by reaching an equilibrium. Such equilibrium is characterized by the fact that any movement can only decrease the area coverage.

Analysis for Two Node Case (1)



- Geometric Parameters as show in figure. Keep C_1 fixed and move C_2 in an arbitrary direction for a small step size ΔL_2.
- Suppose $\Delta L_2 \ll r$.
- Δx, Δy are the projection of ΔL_2 in x and y direction respectively.

Analysis for Two Node Case (2)

- Define a direction vector $\overrightarrow{F_1^2}$ as:

$$\overrightarrow{F_1^2} = \frac{\overrightarrow{C_1C_2}}{\left\|\overrightarrow{C_1C_2}\right\|}$$

- Define another vector $\overrightarrow{D_2}$ as:

$$\overrightarrow{D_2} = \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$$

Analysis for Two Node Case (3)

- The change of area coverage due to movement ΔL_2 can be expressed as:

$$\Delta S_1^2 = |b_{12}| \times \left\langle \overrightarrow{F_1^2}, \overrightarrow{D_2} \right\rangle = \left\langle (|b_{12}| \times \overrightarrow{F_1^2}), \overrightarrow{D_2} \right\rangle$$

where b_{12} can be expressed as a function of $\left\| \overrightarrow{C_1C_2} \right\|$

$$|b_{12}| = 2r \times \sin(2r \sin(\arccos(\left\| \overrightarrow{C_1C_2} \right\| / (2r)))$$

And $\left\| \overrightarrow{C_1C_2} \right\|$ is the distance of the corresponding nodes, it can be easily calculated by knowing node positions.

Analysis for Several Nodes Case

- As illustrate in figure, if circle Ci overlap with nodes as C1,C2,...., Cn, and node i moves ΔLi then the change of area coverage ΔSi can be expressed as:

$$\Delta S_i = \sum_{k=1}^{n} \Delta S_i^k = \sum_{k=1}^{n} |b_{ki}| \times \left\langle \overrightarrow{F_k^i}, \overrightarrow{D_i} \right\rangle = \left\langle \left(\sum_{k=1}^{n} |b_{ki}| \times \overrightarrow{F_k^i}\right), \overrightarrow{D_i} \right\rangle$$

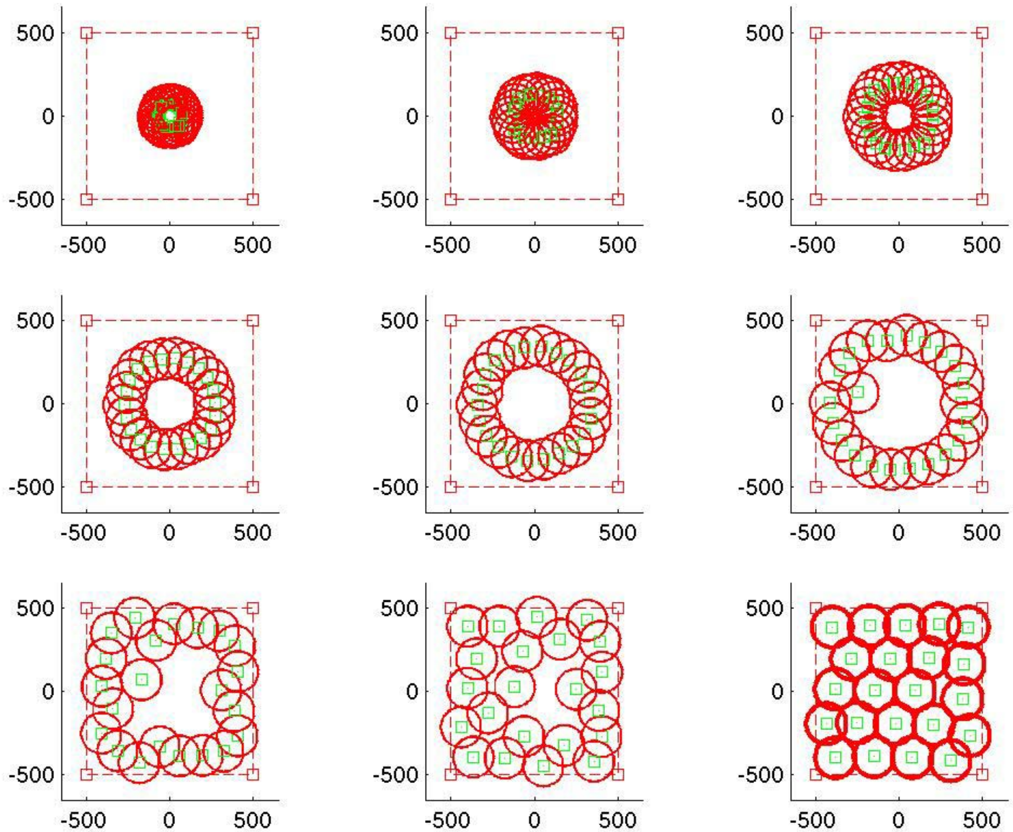
Obviously, For a given step size and only concerning one step, the most efficient movement direction (MEMD) w.r.t. increase of area coverage is the direction consistent with the direction of vector

$$\overrightarrow{D_{opt}} = \frac{\sum_{k=1}^{n} (|b_{ki}| \times \overrightarrow{F_k^i})}{\left\| \sum_{k=1}^{n} |b_{ki}| \times \overrightarrow{F_k^i} \right\|}$$

Parameters and boundary treatment for Mobility Model of Deploy

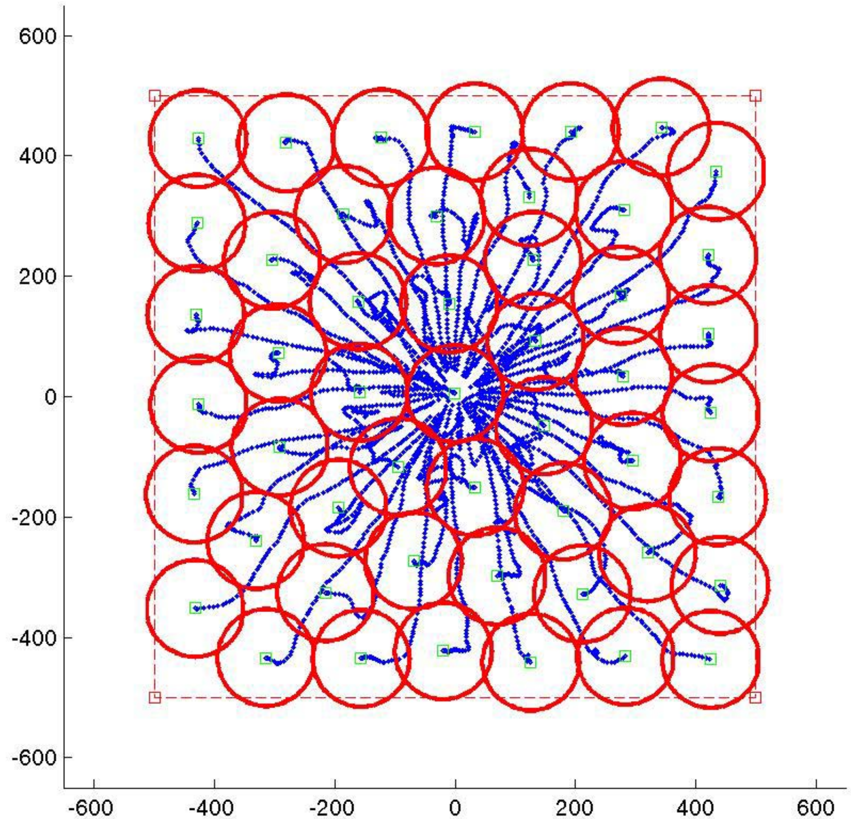
- **Movement directions:** Movement directions are using most efficient movement direction (MEMD).
- **Step size:** The step size for movement is a uniform distributed in an interval as [0,1).
- **Boundary treatment:** For the movement direction of a node that is intersected with boundary, then boundary is treated as if there exists another node outside boundary, which position is a mirror of the node w.r.t. the straight line drawn between two intersected points.

Figure: Matlab simulation of 22 Nodes Movements —w.r.t. a Square Boundary Constraint



Note: successive subplots have movement interval as 135 steps.

Figure: Traces of 50 Nodes Movements



Another Proposed Mobility Model—Fixed Trajectory and keep Node distances (1)

- Except follows, we can use all equations for mobility model of maximum area coverage problem for this mobility model.
  - Certain amount of nodes move to a fixed trajectory, each node have a GPS at hand so it can aware its own position in situ position during movement.
  - During the movement they try to keep the space of each other and at same time also try to not leave each other too much, which can be achieved as former maximum area coverage mobility model except that moving nodes also corresponding to moving boundary.

Another Proposed Mobility Model—Fixed Trajectory and keep Node distances (2)

- However, GPS system for some individual node cannot always works well. For example:

  - ✓ There is a probability for GPS system shut down for certain amount of time;
  - ✓ Because of some situation which force node cannot move according to the information provided by GPS system.

- Correspondingly, there is a probability that a node wanders away too much form its supposed position, such that adjust to its original position in group become difficult.

Another Proposed Mobility Model—Fixed Trajectory and keep Node distances (3)

- We adopt a global adjustment scheme for situations above by using a mobility model as follows:
- For every node, it moves head for a fixed trajectory with certain speed but also subject to some random disturbance.
- During such movement, it also use a control scheme to keep its distance with other nodes. Such control scheme is the same as for maximum area coverage model with a boundary constrain.

Another Proposed Mobility Model—Fixed Trajectory and keep Node distances (3)

- The movement can be described as following steps:

Step 1. When the node lose its position awareness, the control scheme shut down, but after some amount of time it work again. Such situation will modeled as random variables.

Step 2. As node recover from loss position awareness, it starts to request positions information of other nodes. By doing so, it initializes nodes to communicate with each other for position information. Such information is used to adjust positions for each others, until maximum area coverage achieved.

Step 3. repeat step 1 and step 2 until nodes reach the trajectory.

Ask for idea

1. Optimization metric.
2. Estimation methods for a node to predict each other's position.
3. Methods of how to use communication to control node movements.

Opnet Model—UNDER CONSTRUCTION